ANALYSE DES CONTRAINTES RÉSIDUELLES PAR LA MÉTHODE DES COURANTS DE FOUCAULT

ANALYSIS RESIDUAL CONSTRAINT BY EDDY CURRENT METHOD

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Résumé

Le contrôle par courants de Foucault est une des techniques de contrôle non destructif très utilisées dans l'évaluation des matériaux. Les propriétés des aciers dépendent de leur composition, leur microstructure et des contraintes appliquées. Il serait intéressent d'utiliser ces derniers pour caractériser les matériaux et déterminer l'évaluation des contraintes résiduelles qui sont crées par l'application des sollicitations mécaniques. Ces sollicitations seront évaluées par la méthode des courants de Foucault (CF), Les mesures par courants de Foucault sont effectués dans les zones critiques .Le traitements de ces résultats sera comparu aux méthodes traditionnelles (Diffraction…) afin de déterminer une éventuelle relation dans l'évaluation des matériaux entre le contrôle non destructif et destructif.

Abstract

Control by eddy current is one of techniques that's very used in nondestructive evaluation of materials. These processes find an application significant in the determination of the mechanical and metallurgical parameters of materials. The object of this work is to carry out an analysis of the residual stresses in the material created by external solicitations and analysed by eddy currents as a non destructive testing method.
Measurements by the eddy current techniques were taken in the critical zone of specimen. The analysis of the eddy current results will be compared to the results obtained by the traditional methods (X-rays diffraction…) in order to determine a relation between the non-destructive tests and destructive .This work offer the possibility of evaluating microstructural An NDT eddy current is very significant in the microstructures evaluation. We will study the behaviour of the impedance and the phase on the various solicitations applied to materials.
It is possible in the future to determine the life time by analysis of critical zone in the material by eddy current methods

Keyword: NDT, stress, eddy current, impedance, diffraction X
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INTRODUCTION

Control by eddy current is one of techniques that's very well used in nondestructive evaluation of materials[1-2].These processes find a significant application in mechanical and metallurgical determination of materials parameters. The object of this work is to carry out an analysis of the residual stresses undergone in the material by eddy currents as a non destructive testing method. Measurements by eddy current probes were taken in the critical zones. The analysis of the results will be compared with the results obtained by the traditional methods (X-rays diffraction, micrography, micro hardness…) in order to determine a relation between the non-destructive tests and destructive. These works offer the possibility of evaluating microstructural material [3-4]

The experiments carried out showed broad possibilities of analysis by the NDT methods of various metallurgical characteristics evolution using the electric and magnetic processes.

It would be interesting to use this method of characterization and to evaluate the residual stresses which are created by the mechanical solicitations.

These requests will be evaluated by the eddy currents (ET), the interpretation of the signal is most delicate and difficult in the direction or it is always difficult to connect the signal to a mechanical or metallurgical event.

EXPERIMENTAL APPROACH

The parts carried out were subjected to a definite experimental procedure in order to obtain different mechanical modification in material. We have chosen 2024 Aluminum as non ferromagnetic material, the Z 15 CN 16-02 stainless steel type and E24as the ordinary steel for our study**.** A physicochemical analysis was carried out to find out the steel nuance used. The dimension samples are 300x40x2 mm3. They were taken on the same sheet for the same structure.

The test-specimens were cut out and were machined in conformity with the French standard NF A03-160. These test-specimens were subjected to tensile stresses. In order to be in strong solicitation case in the critical zones, we have taken two charges:

- A load higher than the elastic limit (state 1) correspondent to the F1.
- A load close to the rupture limit (state 2) correspondent to the F2.

These forces were applied during one hour. Measurements by probes with eddy current were taken every 05 minutes. Acquisition systems were located on the critical zone level.

The data acquisitions were done by a PC connected by an interface IEEE 488. Optimum condition works were taken in consideration in order to avoid systematic or experimental errors.

EXPERIMENTAL PROCEDURE

Sample 1 subjected to a force F_1 during one hour .The measurement is carried out every five minutes by two eddy current probes

Sample 2 subjected to a force F_2 during one hour. .The measurement is carried out every five minutes by two eddy current probes.

Sample 3 subjected to a force F_1 during one hour .The discharge will be executed to 0. The same sample will be subjected to the force F_2 during one hour. The acquisitions were carried out during each charge every 05 minutes. This method is called in this papers "continuo method"

It would be preferable in the eddy current testing to characterize probe according to the studied case .A feasibility study depends enormously on the used probe and material to be treated. We will quote only the impedance diagram, because it sums up in itself the stability of the used probes. Moreover it enables us to determine the optimal frequency allowing a maximum energy exchange between the probe and material and a satisfactory penetration depth.

The comparison between the results will be done with the X-rays diffraction; it allows amongst others, to determine the crystalline structure of compounds having a periodic electronic density. The various components of the assembly used are. A Diffract meter "X' PERT PRO MPD". The data acquisition will be done on computer with the assistance of software carried out in graphic programming language.

RESULTS AND INTERPRETATION

1- ALUMINUM

An NDT eddy current is very significant in the microstructures evaluation. We will study the behaviour of the impedance and the phase on the various solicitations applied to materials. Indeed for aluminium, for a F1 load we notice oscillations for each step of measurement with an increase in the impedance according solicitation times(figure1-2). Contrary with the phase which decreases and which has behaviour in opposition to the impedance (figure 3-4).For a load locates before the rupture, the number of oscillations is important with higher impedance. Peaks of amplitude are noticed at10 minutes for the F1 charge and with at 25min for the F2l load. That confirms the presence of electromagnetic movement in tested material. These movements cause rather significant amplitudes which can be dislocations and agitation in the structure. We notice that the oscillations are not regular, and that each sample gives a different response in amplitude and position. This remark is confirmed by the method continues, indeed the F1 charge applied to the samples give the different result, we notice the presence of different oscillation in the amplitude between the two samples .The answers of electromagnetic movements in the microstructure are different between the two samples for the same charge.

The F2 load in the case continues, shows a significant reduction in the impedance between F1 and F2. The presence of an important fall of peak amplitude at 25minute implies an increase in conductivity. One can explain this remark by the absence of dislocation gap.(figure5-6). After 30 minutes the material takes again a stable position for an electromagnetic constraint given. The phase gives identical results. (figure7-8)

2- STAINLESS STEEL

The results treatment obtained by eddy currents on the stainless steel samples show for the charge F_1 we remark the oscillations of impedance with an amplitude peak 55,8at 25 minutes. A stability of the impedance with low oscillation is perceived beyond 15minutes around 53,8. For the charge F_2, the impedance decreases contrary to the charge F1 application. The oscillations are more significant with high amplitude (figure9-10). That is explained by the electromagnetic movements, which are more significant in this case, the applied charge F_2 causes movements in the microstructure which is reflected on the conductibility of materials. That can be explained by the grains size which undergoes the material by these requests and thus an agitation micro structural.

The method continues confirms the conclusion quoted for aluminum to see that the electromagnetic movements are random .The internal stress undergoes by the mechanical solicitation differ from a sample to another without differentiating in the content... We notice that the peak shifted at 30 minutes for the same charge. Stability is perceived beyond this time. By the constraint, microstructural movements are created in the stainless steel which is accompanied by electromagnetic movements and consequently by the impedance oscillations. These oscillations are caused by the internal stresses undergoes by traction. Eddy currents use is very significant in the evaluation of the microstructures. We will study the behavior of the impedance and the phase on the various solicitations applied to materials. Indeed for aluminum, for the F_1 charge, we notice oscillations for each measurement step with an impedance increase according to the charge times. Contrary to the phase which decreases and which has a behavior in opposition to the impedance.

For the f2charge locates before the rupture, the oscillations are more marked with higher impedance. Amplitude Peaks are recorded at 10minutes for the charge F_1 and at 25min for the charge F 2. That confirms the presence of electromagnetic movement within material tested. In order to be under the same comparison conditions, in the application of charge f1, we notice that the oscillations are not the same that quoted before.

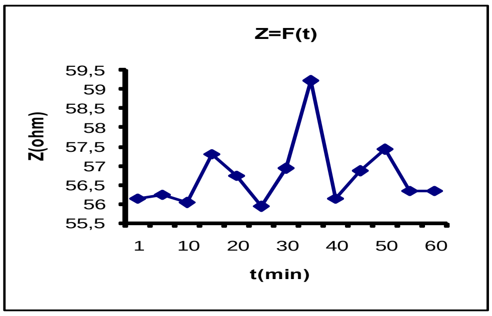

Figure 1: impedance according to solicitation time (charge F1),Al

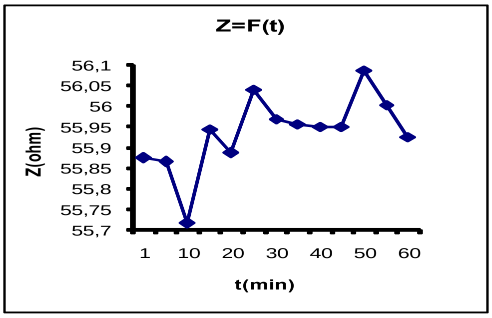

Figure 2: impedance according to solicitation time (charge F2),Al

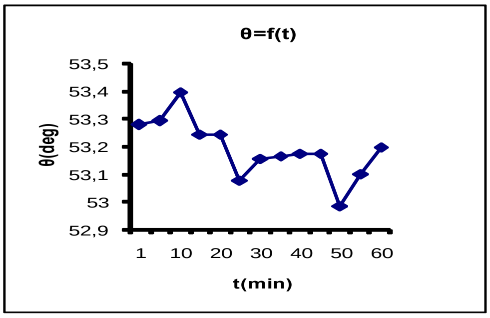

Figure 3: Phase according to solicitation time (charge F1),Al

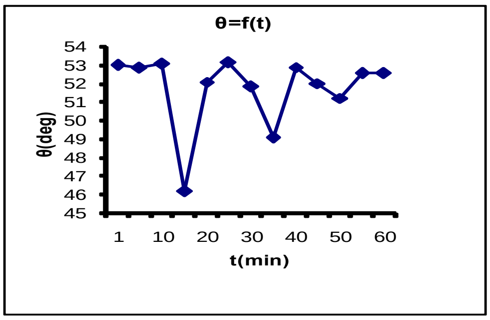

Figure 4: Phase according to solicitation time (charge F2),Al

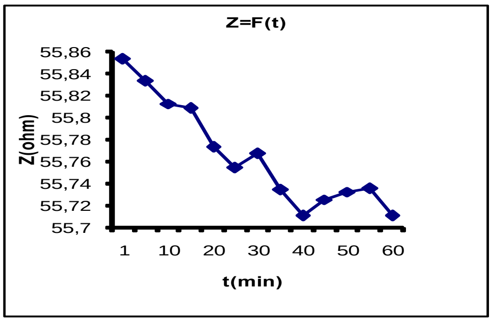

Figure 5: Impedance according to solicitation time (charge continue, F1),Al

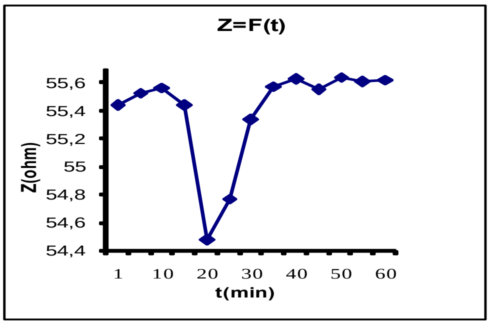

Figure 6: Impedance according to solicitation time (charge continue, 2),AL

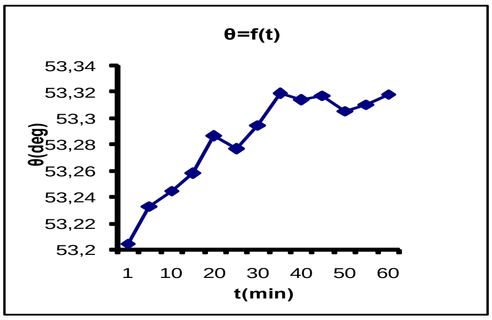

Figure 7: Phase according to solicitation time (case continue, charge F1) Al

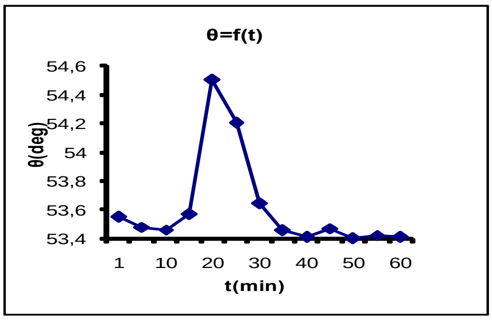

Figure 8: Phase according to solicitation time (case continue, charge F2),Al

Each sample gives a different response in amplitude and position. That is confirmed by the method continues, indeed the charge F $_1$ is roughly and same even when the samples response are different. We notice the presence of oscillation difference between the two samples. That is due to the electromagnetic movements different by the application of the charge.
The charge F2 in the continue case shows a significant reduction in the impedance between F $_1$ and F $_2$. The presence of a peak "significant decrease" at 25 minutes implies an increase in conductivity. We explain by the microstructure change and the gap dislocation absence. After 30 minutes the material takes again a stable position with an electromagnetic constraint given. The phase gives identical results.

3 ORDINARY STEEL

The results for E24 steel are similar to the stainless steel. The tendency of shift of the principal peak of amplitude is more significant for steel(figure 11-12). The amplitudes of the peaks are more significant than those obtained for the stainless steel. The material is more ferromagnetic. The presence of the iron contributed in the magnetization of material, we notice that more time of charge increases more the amplitude increases. For the charge F $_1$ the amplitude passes by a maximum peak at 20 minutes and a minimum peak at 5 minutes, these two values corresponding to an optimal conductivity. This variation can come only from the constraints in material caused by the applied charge. The conclusions on the behavior of the phase according to the charge is similar to those are described previously (figure13-14). For the charge F $_2$, the impedance increases compared to F $_1$, but decreases according to the time charge. The conductivity increases implies that the structural state of material loses these magnetic qualities by the presence of the uniaxial constraint. A significant remark for the case continues, the steel is rich in iron, a presence of carbon makes more difficult its disorganization and thus it is more difficult to carry out its destabilisation.

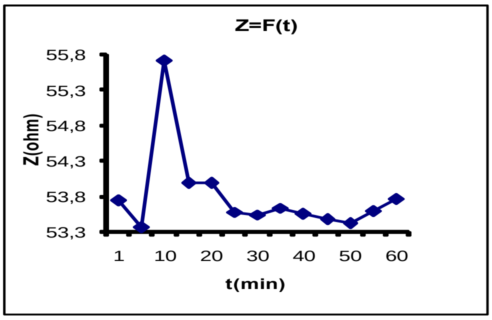

Figure 9: Impedance according to solicitation time (charge F1, stainsteel)

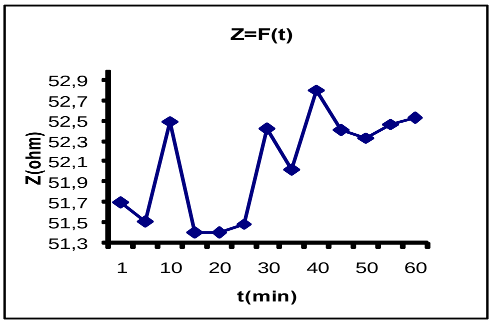

Figure 10: Impedance according to solicitation time (charge F2, stainsteel)

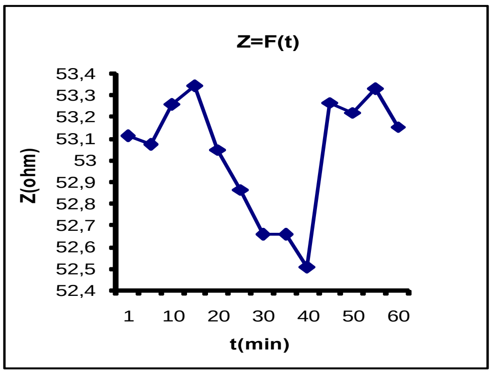

Figure 11: Impedance according to solicitation time (charge F1, E24l)

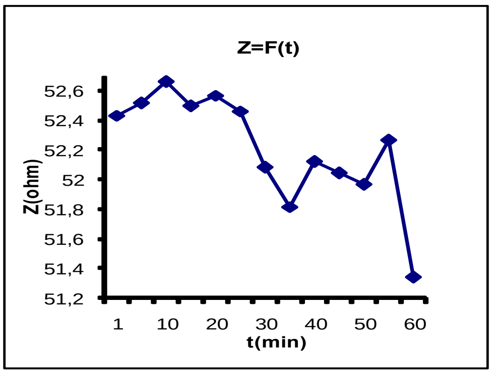

Figure 11: Impedance according to solicitation time (charge F2, E24)

The method continues made it possible to create this agitation .The oscillations number is important and it is significant to notice for the charge located before the rupture creates a number of peaks of significant amplitude. This remark shows instability with this charge in the microstructure (figure 5.28). The phase gives results similar to the preceding case (figure 5.29)
In order to check the results obtained by Nondestructive methods, we carried out tests of diffraction per x-ray. The first observation is that within sight of the results obtained by diffraction of x-rays on the samples subjected to a charge F_1 according to time is different and depend on the constraint. Indeed for the samples subject to eddy current testing, the amplitude of plan (1, 1,0) is different from the sample subjected to the BN or hysteresis loop (figure1bn and EC).
This important observation is confirmed by the non destructive testing methods. For samples subjected for a F_1 charge, the results obtained for example by eddy current are not rigorously the same .The answer of measurement by NDT methods or by X diffraction depend enormously of the residual constraint.
Variations of the position of the lines (peaks) in 2 indicate that residual stresses exist in material. Whereas intensity of the lines (I in counts or numbers blows) or the width with middle height (FWHM in °), inform us about the metallurgical structure of material. Therefore, more the lines are intense plus them are broad and consequently the structure is fine in other words, the crystalline structure has fine grains and conversely. When the material is textured, the lines become less intense and certain plans do not diffract thus, the corresponding lines disappears.
This result is significant because it makes possible to determine the existence of the residual stress and to proceed to its quantification. This result is confirmed by X-rays diffraction. Indeed we notice the same shifts of the principal peak towards the right of the samples according to the charge applied.
The second remark is that the amplitude increases if the charge F_1, F_2 or the continuous test were applied (Figure). we noticed the shift of the principal position of the peak when it subjected to F_1, F_2 or continuous charge in the NDT methods as the results obtained by x diffraction . Moreover The advantage of this work that the NDT analyses allows it possible to verify in real time the evolution of the peak amplitude according to the charge time .

CONCLUSION

The investigation in this field being very competitive, The eddy currents NDT techniques can give by their sensitivities a significant place to solve complex mechanical and metallurgical problems in industry and the aerospace in particular.
The simplicity of this technique and the various advantages which they offer in the determination of the intrinsic properties of materials allow the evaluation of material. Analysis NDT results confirm that the oscillations obtained by eddy current due to constraints in the material in the real-time caused by the tensile stress. Results obtained by NDT was confirmed by X diffraction.
The same manner as x-diffraction, the NDT techniques shows fluctuations on the peaks amplitudes caused by the uniaxial stress. The most significant result treated by eddy current explain clearly that the samples are in unstable states by the constraint presence .This constraint would be quantified in the future and allows the installation prediction life analysis.

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